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Dated 18 March 2004

Patents Form 1/77
Patents Act 1977
(Rule 16)

15 NOV 2000

The Patent Office

16NOV00 E584038-2 D02917
P01/7700 0.00-0027886.1

Request for grant of a patent

The Patent Office
Cardiff Road
Newport
South Wales NP10 8QQ

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1. Your reference

1842301/AM

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2. Patent Application Number 15 NOV 2000 **0027886.1**

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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

RaceTrace Inc.
1601 Trapelo Road
Waltham
Massachusetts 02451
USA

Patents ADP number *(if known)* 08023764001

If the applicant is a corporate body, give the country/state of its incorporation — Country: **USA** State: **Delaware**

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4. Title of the invention

SPREAD SPECTRUM TAG TRACKING

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5. Name of agent — **Beresford & Co**

"Address for Service" in the United Kingdom to which all correspondence should be sent — **2/5 Warwick Court**
High Holborn
London WC1R 5DH

Patents ADP number 00001826001

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6. Priority details

Country	Priority application number	Date of filing

7. If this application is divided or otherwise derived from an earlier UK application give details

Number of earlier application — Date of filing

8. Is a statement of inventorship and or right to grant of a patent required in support of this request?

YES

9. Enter the number of sheets for any of the following items you are filing with this form.

Continuation sheets of this form	
Description	5 + 5 CN
Claim(s)	
Abstract	
Drawing(s)	

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents form 7/77)*	**1 + 4 COPIES**
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for Substantive Examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature Beresford & Co Date 15 November 2000

BERESFORD & Co

12. Name and daytime telephone number of person to contact in the United Kingdom

Alan MacDougall

Tel: 020 7831 2290

Patents Form 7/77
Patents Act 1977
(Rule 15)

15 NOV 2000
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The Patent Office

Statement of Inventorship and of right to grant of a patent

The Patent Office
Cardiff Road
Newport
South Wales NP10 8QQ

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1. Your reference

1842301/AM

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2. Patent Application Number

accompanying application reference 1842301

15 NOV 2000

0027886.1

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3. Full name of the or each applicant

RaceTrace Inc.

---

4. Title of the invention

SPREAD SPECTRUM TAG TRACKING

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5. State how the applicant(s) derived the right from the inventor(s) to be granted a patent

By the employment of the inventors by Scientific Generics Limited and by virtue of an agreement between Scientific Generics Limited and the applicant.

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6. How many, if any additional Patents Forms 7/77 are attached to this form?

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7. I/We believe that the person(s) named over the page (and on any extra copies of this form) is/are the inventor(s) of the invention which the above patent application relates to.

Signature Beresford & Co   Date 15 November 2000

BERESFORD & Co

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8. Name and daytime telephone number of person to contact in the United Kingdom

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Patents Form 7/77

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1 Spread Spectrum Tag Tracking

2 BACKGROUND

Radio signals have been and continue to be used extensively for the purpose of locating and tracking objects.

For location the position is normally computed by analysing signals that are received from two or more different geographically dispersed transmitters. There are a number of different techniques for doing this, including CURSOR as defined in EP0303371 and the commercially available GPS system. The various techniques include time-of-flight or phase measurement and may or may not require the transmitter network to be synchronised.

Tracking an object may be accomplished using the same techniques as for location and sending the result to a monitoring point remote from it. However, more usually the object has a transmitter that emits a radio signal. The location of the source of the radio signal is identified using a number of different techniques including direction finding using directional antennae and arrays of receivers that enable the difference in the time-of-arrival or phase of the received signal to be measured and hence the location computed.

This invention describes a new system for tracking a tag's position in real time by measuring various parameters of spread spectrum radio signals emitted by the tag. The tag is the device attached to an object, the location of which is required.

3 DESCRIPTION OF THE INVENTION

The main elements of the Tracking System are:

- It consists of a number of independent receivers geographically dispersed, the number being at least equal to the number of dimensions required for tracking the tag. So to track in two dimensions at least two receivers are required. The receivers are fixed in known geographic locations.
- Each tag being tracked includes a transmitter that transmits a radio signal receivable by a number of receivers in the network at least equal to the number of dimensions required for tracking. The tag is mobile and may move.
- The fixed receivers receive the signal transmitted by the mobile tag and measure various parameters of the signal.
- The measurements made by the receivers are communicated to a device (Position processor) which compares the measurements from the different receivers and derives the location of the tag. The position processor may be located with one of the receivers or at a separate location.
- The signal transmitted by the tag may be a CW narrow-band radio transmission or a signal modulated on a higher frequency carrier rather than the carrier itself. In this case the method of location determination is based primarily on measuring the phases of the received signals.
    - The choice of CW signal frequency (or modulating frequency) depends on the accuracy required and the area of coverage within the cyclic ambiguity of the signal wavelength. The cyclic ambiguity places the distance from any particular receiver on one of a multiplicity of concentric circles.
    - The indeterminate phase of the respective oscillators at power-on leads to the need for initial calibration of the transmitter. Once calibrated (or initialised) the system is able to track the tag position continuously and without cumulative error.
    - The tags may transmit on a time division basis (or be interrupted) provided that successive transmissions remain phase continuous with one another.
    - The transmitted signal may consist of two harmonically related CW tones locked to the same fundamental signal, where the signal phase used for measurement purposes is the difference between the two, rather than the phase of just one. For example two tones *a* and *b* may be chosen such that *a-b* is 1MHz, giving a wavelength of 300m.

- The dual tone system may be up-converted in the tag using a mixer (multiplication) for transmission in any radio band, and then converted back down to baseband (once again using a mixing process) in the receivers, without destroying the basic phase measurement (the phase relationship between the two tones), and without the need to phase lock the local oscillators used for transmit and receive.
- Extending the dual tone system to incorporate three tones such that the difference frequencies *a-b* and *a-c* are significantly different (for example 100kHz and 5MHz), allows the cyclic ambiguity of the measurement of phase to be unique over a much larger area - at least equal to the wavelength of the smaller difference frequency - and yet providing the resolution of the higher difference frequency.
- The three tone system furthermore allows (by correct design of the transmitter and receiver) the unknown initial startup phase of the reference oscillator to be eliminated, and therefore an absolute position to be computed without the need for initial calibration.
- The ability to arbitrarily mix the two or three tone transmissions up to different radio bands, enables the system to frequency hop where each successive transmitted burst may be on a different frequency. Typically such a system would hop sequentially (and psuedo randomly) through a set of frequencies spread across a wider band of use.
- The two or three tone systems may transmit their tones sequentially rather than having to transmit bi- or tri-tone signals. This allows lower cost less linear transmitters to be used by eliminating the troublesome intermodulation products.
- Each tone being transmitted is extremely narrow band and can be detected by a narrow band receiver limited only by the stability of the transmit and receive oscillators and the bandwidths of the bandpass filters, thereby improving the signal to noise performance and ability to measure phase accurately.
- The signal could be modulated in order to convey information from the tag to the receiver network. In this case only the carrier of the signal is used for calculating the tag position.
- The use of pulsed transmission coupled with frequency hopping allows a large number of tags to operate simultaneously in a given area and frequency band.
- The use of narrow band signals and frequency hopping allow the signals to be received in the presence of very high levels of interference, given a high level of robustness.

- The signal transmitted by the tag may be broadband, in which case the receivers measure the time of arrival of the signal in order to locate the object. Embedded within this broadband signal may be tonal structures, the phase of which can be measured to produce better location accuracy.

- The broadband transmitted signal may be pulsed, or utilise a broadband spreading sequence such as a suitable PRBS code. In a pulsed system the time of arrival of the pulse is measured directly. In the direct sequence spread spectrum system the time of arrival is determined from the decorrelator in the receiver.
- The tag may transmit continuously or on a time division (pulsed) basis.
- A system using short pulse transmissions may accommodate many tags on a time shared basis using an Aloha type contension scheme or a more complex contention sense algorithm.
- A system using broadband PRBS based transmissions may support many tags on the basis of code orthogonality coupled with the coding gain that can be achieved or the use of a number of different codes.
- The DSSS technique may be used to spread a sinusoidal carrier generated by the tag. The receiver recovers this carrier in the decorrelation process and measures its phase to derive a more accurate position than can be achieved using time of flight alone.
- As described for the frequency hopping multi-tone system above, the DSSS technique may be used to spread dual or triple frequency sets.
- The use of a triple frequency set directly spread by a suitable PRBS code allows direct time of flight measurement supported by the accurate and absolute location of the dual difference tone technique described.
- Using DSSS techniques spreads the signal energy across the band thereby minimising the non-linear effects of the radio filters and propagation channel, and provides enhanced immunity against narrow band interferers.
- Data generated by the tag or input to it may be transmitted to the receivers using several different DSSS modulation techniques.
- The use of time division (pulsed) transmissions and multiple codes with low autocorrelation characteristics allows a large number of tags to operate simultaneously in a given area.

- In the case that the network of receivers are synchronised, but the mobile tag transmitter is not, a third receiver is required in order to resolve the clock offset between transmitter and receiver network.
- The network of receivers does not need to be syncronised: syncronisation can be achieved by using an additional transmitter (similar to the tag) installed at a known location. It could be co-located with one of the receivers or at a unique location, provided that the reference transmitter location is known.
- Each receiver may also incorporate a transmitter function that is used to calibrate the timing offsets between the receivers of the receiver network, instead of having a separate additional transmitter.

- In the case that each receiver incorporates the transmitter function for network calibration, only the locations of two receivers is required in order for the entire network to be self calibrating in order to determine the locations of the receivers.

4 APPLICATIONS

The system described may be used for a variety of different applications in which the location of a tag needs to be known by the system. It is ideal for systems operating within a defined area, and which require continuous real time tracking of the tag. It could also be used in applications in which the location of the tag is relayed back to the tag using a communications link. The low complexity level enables the tag to be made extremely small and cheap.

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